

AMENDMENTS TO THE CLAIMS

1. (Original) A semiconductor device comprising:
a first dielectric layer over a substrate;
copper (Cu) or a Cu alloy inlaid in the first dielectric layer; and
a composite capping layer on the inlaid Cu or Cu alloy, the composite capping layer comprising:
a layer of beta (α)-tantalum (Ta) on an upper surface of the inlaid Cu or Cu alloy;
a layer of tantalum nitride on the layer of α -Ta; and
a layer of alpha (α)-Ta on the layer of tantalum nitride.
2. (Original) The semiconductor device according to claim 1, wherein the composite capping layer is formed in a recess in the inlaid Cu or Cu alloy such that an upper surface of the α -Ta layer is substantially coplanar with an upper surface of the first dielectric layer.
3. (Original) The semiconductor device according to claim 2, wherein:
the layer of α -Ta has a thickness of 25Å to 40Å;
the layer of tantalum nitride has a thickness of 20Å to 100Å; and
the layer of α -Ta has a thickness of 200Å to 500Å.
4. (Original) The semiconductor device according to claim 1, wherein:
the layer of α -Ta has a thickness of 25Å to 40Å ;
the layer of tantalum nitride has a thickness of 20Å to 100Å; and
the layer of α -Ta has a thickness of 200Å to 500Å.
5. (Original) The semiconductor device according to claim 3, further comprising:
a diffusion barrier lining and opening in the first dielectric layer; and
the Cu or Cu alloy on the diffusion barrier filling the opening.
6. (Original) The semiconductor device according to claim 3, further comprising:

a second dielectric layer over the first dielectric layer; and

Cu or a Cu alloy inlaid in an opening in the second dielectric layer in electrical contact with the upper surface of the α -Ta layer.

7. (Original) The semiconductor device according to claim 6, further comprising an α -Ta diffusion barrier lining the opening in the second dielectric layer.

8. (Currently Amended) The semiconductor device according to claim 6, wherein the opening in the second dielectric layer, is a dual damascene opening, and the method comprising filling the dual damascene opening is filled with Cu or a Cu alloy ~~to form an~~ forming interconnect comprising a lower via in contact with an upper line.

9. (Currently Amended) The ~~method~~ semi-conductor device according to claim 8, further comprising a composite capping layer on the Cu or Cu alloy filling the opening in the second dielectric layer, the composite capping layer comprising:

a layer of β -Ta on the Cu or Cu alloy;

a layer of tantalum nitride on the layer of β -Ta; and

a layer of α -Ta on the layer of tantalum nitride.

10. (Original) A method of manufacturing a semiconductor device, the method comprising:

forming an opening in a first dielectric layer;

filling the opening with copper (Cu) or a Cu alloy; and

forming a composite capping layer on the Cu or Cu alloy, the composite capping layer comprising:

a layer of beta (α)-tantalum (Ta) on an upper surface of the Cu or Cu alloy;

a layer of tantalum nitride on the layer of α -Ta; and

a layer of alpha (α)-Ta on the layer of tantalum nitride.

11. (Original) The method according to claim 10, comprising:

forming a recess in the upper surface of the Cu or Cu alloy before forming the composite capping layer; and

chemical mechanical polishing (CMP) after forming the composite barrier layer such that an upper surface of the α -Ta layer is substantially coplanar with an upper surface of the first dielectric layer.

12. (Original) The method according to claim 11, comprising forming a diffusion barrier lining the opening before filling the opening with Cu or a Cu alloy.

13. (Original) The method according to claim 11, comprising:
forming the layer of α -Ta at a thickness of 25Å to 40Å;
forming the layer of tantalum nitride at a thickness of 20Å to 100Å; and
forming the layer of α -Ta at a thickness of 200Å to 500Å.

14. (Original) The method according to claim 10, comprising:
forming the layer of α -Ta at a thickness of 25Å to 40Å;
forming the layer of tantalum nitride at a thickness of 20Å to 100Å; and
forming the layer of α -Ta at a thickness of 200Å to 500Å.

15. (Original) The method according to claim 11, comprising depositing the α -Ta, titanium nitride and α -Ta layers by physical vapor deposition (PVD).

16. (Original) The method according to claim 11, further comprising:
forming a second dielectric layer over the first dielectric layer;
forming an opening in the second dielectric layer; and
filling the opening in the second dielectric layer with Cu or Cu alloy in electrical contact with the upper surface of the α -Ta layer of the composite capping layer.

17. (Original) The method according to claim 16, comprising lining the opening in the second dielectric layer with an α -Ta diffusion barrier layer before filling the opening with Cu or Cu alloy.

18. (Original) The method according to claim 16, wherein the opening is a dual damascene opening, the method comprising filling the dual damascene opening with Cu or Cu alloy to form an interconnect comprising a lower via in contact with an upper line.

19. (Original) The method according to claim 18, further comprising forming a composite barrier layer on the Cu or Cu alloy in the opening in the second dielectric layer, the composite barrier layer comprising:

- a layer of β -Ta on the Cu or Cu alloy;
- a layer of tantalum nitride on the layer of β -Ta; and
- a layer of α -Ta on the layer of tantalum nitride.

20. (New) The semiconductor device according to claim 1, wherein the composite capping layer consists essentially of the layer of β -Ta, the layer of tantalum nitride and the layer of α -Ta.

21. (New) The semiconductor device according to claim 20, wherein the composite capping layer consists of the layer of β -Ta, the layer of tantalum nitride and the layer of α -Ta.

22. (New) The semiconductor device according to claim 1, wherein the layer of α -Ta has a thickness of 200Å to 500Å.

23. (New) The method according to claim 10, wherein the composite capping layer consists essentially of the layer of β -Ta, the layer of tantalum nitride and the layer of α -Ta.

24. (New) The method according to claim 23, wherein the composite capping layer consists of the layer of β -Ta, the layer of tantalum nitride and the layer of α -Ta.

25. (New) The method according to claim 10, comprising forming the layer of α -Ta has a thickness of 200Å to 500Å.